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Electrical Performance of Integrated Hybrid Power Generation System with Thermoelectric Generator

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Abstract: - Hybrid generation system (HGS) consist of a glass heat collector (HC) which is placed in front of silicon thin film solar cell (STC) to collect heat energy and also allow visible part of light energy to STC through HC. Infrared heat lamp is used as a source of HGS. In the Hybrid generation (HG) system two different principles are concerning. First one, infrared heat energy indirectly produces electricity by first producing heat and then generating electricity by means of thermo electric generator (TEG). Second principle, visible part of light from the lamp passed through the HC and hits the STC which directly produces electricity. From this experiment conclusion are drawn, the concentrated HGS system 12.8% effective then the non-concentrated systems. The HG system with Concentrator, Glass heat collector in front of STC and TEG are consider as a reasonable alternative to the thermal/ electrical hybrid generation system.

Keyword: - Hybrid generation system (HGS), Heat collector (HC), Silicon thin film solar cell (STC), Thermo electric generator (TEG).

I. INTRODUCTION

In the search of alternative sources of renewable energy, it is generally accepted that there is a vast amount of energy available from the sun, energy utilized from the sun for power production are two types that is visible part of light and heat (infrared heat radiation) by using Photovoltaic cells (PV) and thermoelectric generator (TEG).

Photovoltaic (PV) cells produces electricity when it exposed to sunlight due to photovoltaic effect. Photovoltaic effect causes photovoltaic cell absorbs photons of light energy which release electrons, these free form of electrons are captured by electrical circuit resulting electric current that is electricity. Single photovoltaic cell produces electric power output is very small, so multi number of single cells are connected together and encapsulated to form a module. These module is also called as panel. These panels produce a specific current and voltage when illuminated. PV modules are connected in series and parallel arrangement to meet voltage and current requirements [1].Thermoelectric generators (TEG) are all made up of solid-state devices that convert heat energy into electric power output based on the principle of seebeck effect. TEG is the one type of Thermo electric module (TEM) [2]. The basic structure of a TEM is, which use the thermoelement for electricity production. A series arrangement of semiconductor material P- and N- type for electricity production. In order to increase the operating voltage a number of thermoelements electrically connected in series and to increase thermal conductivity of materials by parallel arrangement. These series and parallel arrangement semiconductor materials forms TEM. In other words, a TEG system consist of three parts that are a cooler surface, a heater surface and a TEM in between heater and cooler surface. TEG consist of two surfaces, for electric power production one side of the material surface maintain at hot side means virtually other surface of material have to maintain lower temperature. As a result temperature difference between (ΔT) hot and cold sides of TEG produce an electric voltage (V). When it connected to the external load (R_L) [2, 3].

II. HYBRID POWER GENERATION SYSTEM (HGS)

Notable problem in solar engineering are solar energy conversion efficiency is limited by solar cell due to inefficient utilization of wide solar spectrum with only one semiconductor material and the majority of infrared energy from sources is converted into waste heat and the temperature rise of PV cell which casus loss of efficiency and lifetime. To overcome this problem and effective use of both light and heat sources, the combinations have been considered. Now a day's photovoltaic and thermoelectric generator has gained wide attention in hybrid generation system.

A. Description of devices used for HGS

The electric devices used in the hybrid generation system are disused below.

1) *Silicon Thin Cell (STC):* Photovoltaic technology used to convert incident visible part of radiation into electric energy which become a one of the highly competitive in recent years. In order to create high energy production and light weight of the cell these properties of silicon thin film solar cell attract the research towards this. Amorphous silicon (a-Si) solar cells belong to the category of silicon thin-film. Especially amorphous types STCs are absorb 150 $mW/nm/cm^2$ of solar spectrums at a wave length range of 50 to 760 nm. Which is much better than the micro crystalline

type STCs [4]. *Specifications of Solar cell:* Type: Silicon thin cell Amorphous, Open circuit voltage: 5 Volts DC, Short circuit current: 0.5 A, Max power output: 2.5 Watts, Dimensions: Dia.100 mm, Thickness: 2 mm, operating temperature: 4 to 80 ^{0} C.

2) *Thermo Electric Generator (TEG):* Thermoelectric generators (TEG) used in this work based on traditional material Bismuth telluride (Bi_2Te_3). In production of electric power TEGs are environmentally friendly. There is no moving parts, highly reliable and silent [5]. *Specification of the device:* Type no TGM-127-1.4-2.5, produced by nipponindia (Indian website www.nipponindia.com) dimensions 40×40×3.3 mm^3, electrical resistance at temperature interval 323–473 K, 5–6 Ω, over the external matched resistance with maximum power generated around 1.5 W (voltage of about 2.4 V and current around 0.6 A). Compared to other renewable energy resources significant dis advantage is low figure of merit (Z) in the TEGs and low quality factor. [9].

3) *Infrared Heat Lamp:* Solar energy emitted by the sun may vary based on climate, weather condition and also wind speed. In order to get constant energy (both heat and light energy). Infrared lamps are electrical devices which emit more infrared radiation. 250 W lamp, 90% of energy transmitted as infrared which made up of Philips Company. 20 cm from front of the bulb will produce irradiation of 350 mW/cm2 at that point. So the collector is placed at 20 cm from front of the bulb to get constant intensity of radiation [6]. The features of lamp are instant, accurately controllable radiant heat and easy installation is possible.

B. Description of components used for HGS

Components used for the hybrid generation system arrangement and its specification of work are discussed briefly.

1) *Concentrator:* Fresnel lens is used to concentrate the solar radiations at a particular focal length based on its construction. Specification of lens: Focal length- 30 cm, Dimension-180*260*0.4 mm, Material- PVC, Groove pitch-0.30 mm. A chain of prism essentially is represented as Fresnel lens. The slope of the each prism represents lens surface [7].

2) *Heat Collector (HC):* Heat is the main part of HGS, heat collector s made of annealed glass which can with stand maximum temperature of 500 °C. The optical efficiency of glass is 95% and emissivity 0.93. The collector chamber is in cylindrical shape of diameter 10 cm and height 5 cm. This is evacuated inside to avoid the heat loss by convection from inside heat collecting tube and surrounding. To carry the heat from HC to TEG hot water chamber, normal water is used as heat transferring medium.

C. Instruments used for measurement

The following measuring instruments are used in this experiment. Thermocouple with digital display indicator, model – DTI. Al/Cr thermocouple- J type, temperature range - 0 to 200 °C. Multimeter, current range – 200 μA to 10 A, voltage rage – 200 mV to 600 V. Rheostat- 120 Ω variable type.

III. OPERATION OF HGS

The line diagram of experimental setup for the study of the hybrid generation system is shown in figure 1. The experimental setup consist of following device used in the power generation system that are silicon thin film solar cell, thermo electric generator and infrared heat lamp and components used in the system are heat collector, Fresnel lens, heat transferring medium (water), main tank, reservoir tank and TEG power generation system. The measuring instruments used in the power generation system are temperature indicator, ammeter, voltmeter, and rheostat. The main tank is consider as a constant head tank which is filled by using a pump from the reservoir tank. The fluid over flow from the tank is collected in collecting tank and redirect back to the reservoir tank. The main tank is connected to both heat collector and also cooling tank of TEG. The flow rate from cooling tank and hot fluid tank are measured by using laboratory beakers of capacity 500 ml.

The calibrated thermocouples which are provided at inlet and outlet of collecting tank for measuring the temperature. Voltage and current from TEG and STC are measured by using a multimeter. STC is placed directly under HC at a distance 10 cm to avoid heating of panel. The infrared heat lamp is kept directly above TEG and STC test section, such that the intensity of light radiation from the heat lamp is 350 mW/cm^2. The intensity of light is made constant throughout the experiment. Fresnel lens used as a concentrator and it concentrate both infrared heat and light energy to HC and STC from the distance of 5cm and 15cm.

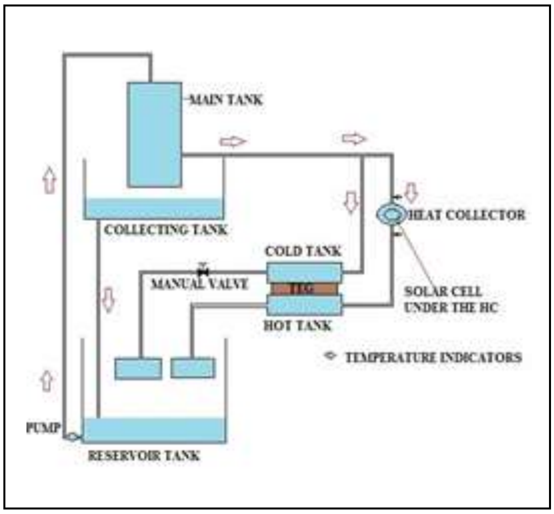

Fig. 1, Line diagram of hybrid generation system

The experimental setup of the hybrid generation system is shown in the Fig. 2. Fluid from the main tank flows to the HC through silicon tube. HC placed above the STC which is made upon annealed glass consists of spherical tube. Infrared heat lamp emits both visible part of light and infrared heat which passes through the HC hits on the STC. HC absorb most of the infrared heat and also allow maximum amount of visible part of the light over the STC, which used to produce the power in STC when it is connected to the load. These arrangement of heat collector control the temperature of STC. The heat energy from HC transferred by the flow of water to the hot chamber which placed under the TEG. Cold water from main tank flows to the cold chamber which is placed above the TEG. The temperature difference between the hot and cold side of TEG produces power based on the principle of seebeck effect. The maximum temperature between hot and cold side of the TEG produces maximum amount of power.

Fig. 2, Experimental setup of hybrid generation system

IV. ELECTRICAL PERFORMANCE OF HGS

A. Electrical Characteristics of STC

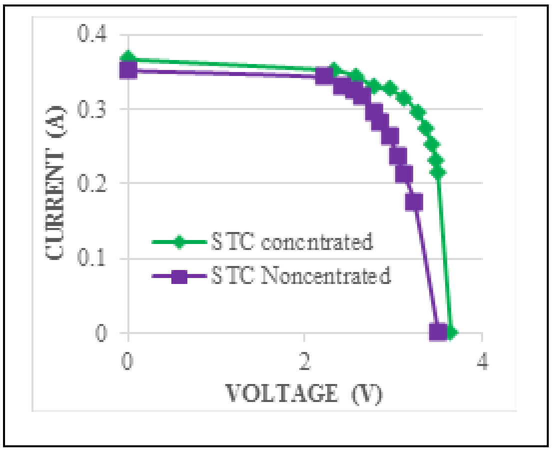

Fig. 3, I-V Characteristics of silicon thin film solar cell

The current and voltage characteristics (I-V characteristics) curve (Fig.3) shows the concentrated and non-concentrated electrical behavior of the STC. Current is inversion proportional to voltage. From the graph (Fig. 3) which was absorbed that open circuit voltage (V_{oc}) is maximum at no load condition and at full load condition maximum short circuit current (I_{sc}) is obtained. STC internal resistance (R_{in}) and load resistance (R_L) affects it linearity of current and voltage.

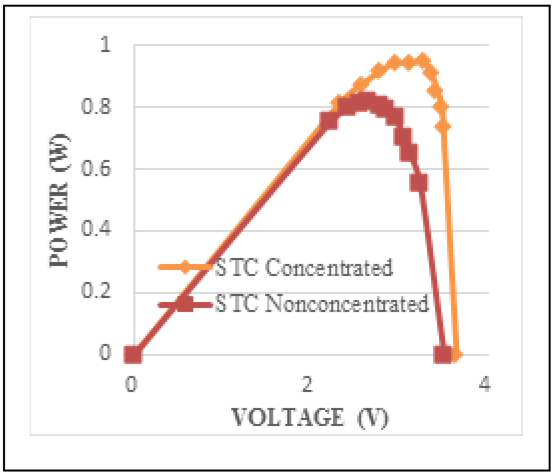

Fig. 4, P-V Characteristics of silicon thin film solar cell

The electric output power of the silicon solar cell depends on the visible part light falls over surface, temperature and internal resistance (R_{in}). Maximum power produced at loaded condition when the internal resistor and the load resistor are equal. The output power of the STC for both concentrated and non-concentrated are plotted in the graph (Fig.4). The maximum power output from concentrated and non-concentrated type silicon thin film solar cell are 949 mV and 822 mV .

B. Electrical Characteristics of TEG

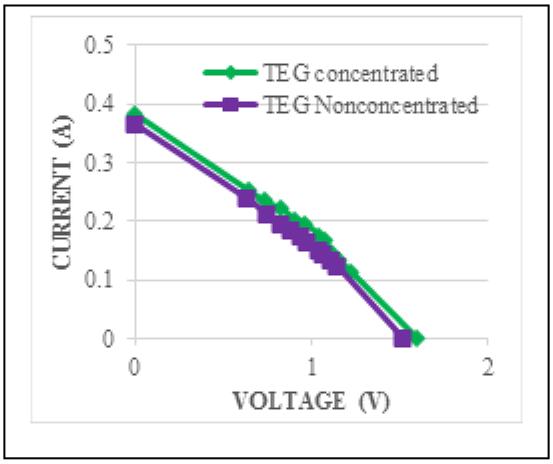

Fig. 5, I-V Characteristics of Thermoelectric generator

I-V characteristics of thermoelectric generator are based on its temperature difference (ΔT) between the hot and cold surfaces, internal resistor (R_{in}) and load resistor (R_L). From I- V characteristics graph (Fig. 5) understand that the maximum open circuit voltage (V_{oc}) is obtained when circuit at no load condition and at full load condition maximum short circuit current (I_{sc}) is obtained. The electrical behavior of thermoelectric generator shows that maximum power is obtained at matched load condition.

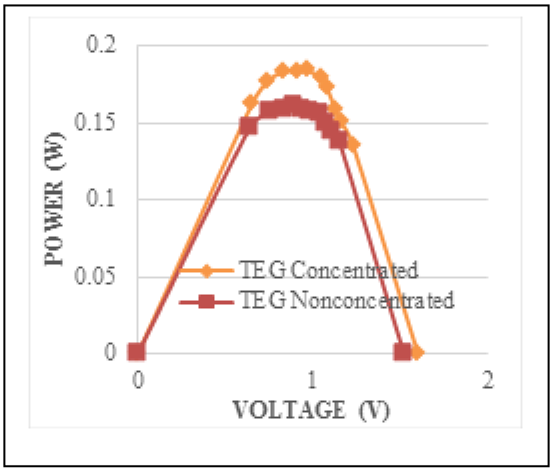

Fig. 6, P-V Characteristics of Thermoelectric Generator

The electric output power of the thermoelectric generator depends on the temperature difference between hot and cold surface, seebeck coefficient (α) and internal resistance (R_{in}). At loaded condition when the TEG internal resistor and the load resistor are at matched load condition the maximum power is obtained. The Fig. 6, shows at half of the open circuit voltage maximum power point located. The output power of the TEG for both non- concentrated and concentrated are plotted graph (Fig. 6). The maximum power output of concentrated and non-concentrated type TEG are 184 mV and 161 mV when water is used as a heat transferring medium.

CONCLUSION

From result we observed that the maximum power from the concentrated HG system is 1.127 W and the non-concentrated type HG system is 0.983 W. The efficiency of concentrated HG system 12.8 % higher than the non-concentrated systems. Thus, we conclude that the HGS with the Concentrator, TEG and Glass heat collector in front of the STC can be consider as a reasonable alternative to the electrical hybrid generation system. The temperature of STC are controlled by this HG system arrangement and which will lead to increase the lifetime and efficiency of the system. The advantage of HG system without moving parts and has zero emission and requires very less maintenance. Future work should be focus to improve both the electrical/thermal efficiency of hybrid generation system and its cost reduction so as to make it more competitive.

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